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BIOSTRATIGRAPHY OF SOME UPPER CRETACEOUS / LOWER EOCENE SUCCESSIONS IN SOUTHWEST SINAI, EGYPT

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ABSTRACT

Two Upper Cretaceous and Lower Eocene successions from southwest Sinai, at Wadi Feiran and Gabal Matulla, were studied biostratigraphically on the basis of their planktonic microfossils, 58 planktonic foraminifera and 103 calcareous nannofossil species have been identified. The abundance of marine microfossils led to the subdivision of the studied sections into 13 planktonic foraminiferal and 12 calcareous nannoplankton biozones. These zones were correlated with those recorded in Egypt and in other parts of the world.

The Cretaceous /Paleogene (K/P), the Early/Late Paleocene (D/Th) and the Paleocene/Eocene (P/E) boundaries are defined and discussed. A paleontologic gap was revealed at the K/P boundary due to the absence of the latest Maastrichtian calcareous nannoplankton Micula prinsii Zone as well as the absence of the earliest Paleocene Markalius inversus Zone and the planktonic foraminiferal Globigerina eugubina Zone. The Early / Late Paleocene (D/Th) boundary is placed at the top of M. uncinata Zone and at the upper part of the NP4 Zone of the studied sections. The Paleocene/Early Eocene (P/E) transition cuts across the upper part of Esna Formation and locates at the extinction level of Morozovella velascoensis which coincides with the NP9/NP10 zonal boundary at Gabal Matulla and pass through the upper part of the zone NP9 at Wadi Feiran.

INTRODUCTION

The Upper Cretaceous-Lower Paleogene rocks are well developed in Egypt. These rocks have attracted the attention of many stratigraphers and paleontologists because they are highly fossiliferous and well exposed. The study deals with the lithostratigraphy and biostratigraphy of the Upper Cretaceous / Lower Eocene successions of southwest Sinai (Wadi Feiran and Gabal Matulla) using both planktonic foraminifera and calcareous nannoplankton (Fig. 1).

The sequence of the studied sections is subdivided into three formations arranged in chronological sequence as Sudr, Esna and Thebes Formations (Figs. 2,3). The study aims to throw more light on the Cretaceous/Paleogene, Early /Late Paleocene (Danian/Thanetian) and Paleocene/Eocene boundaries in the studied sections. This study has been achieved through 170 samples collected from the Upper Cretaceous-Lower Eocene successions of the studied area. An Olympus polarized microscope with X 100 oil immersion lens has been used to identify the calcareous nannofossils and a binocular microscope for the identification of the foraminifera.

In the present study the Maastrichtian zonal scheme of Caron (1985) and the Early Paleogene zonal scheme of Toumarkine & Luterbacher (1985) are used.

The nannoplankton zonation is discussed on the basis of Sissingh (1977) zonation for the Late Cretaceous and that of Martini (1970, 1971) for the Early Paleogene. The identified biozones are shown in Figs (2,3). The identified species are illustrated in the stratigraphic distribution charts of Figs. (4-7).

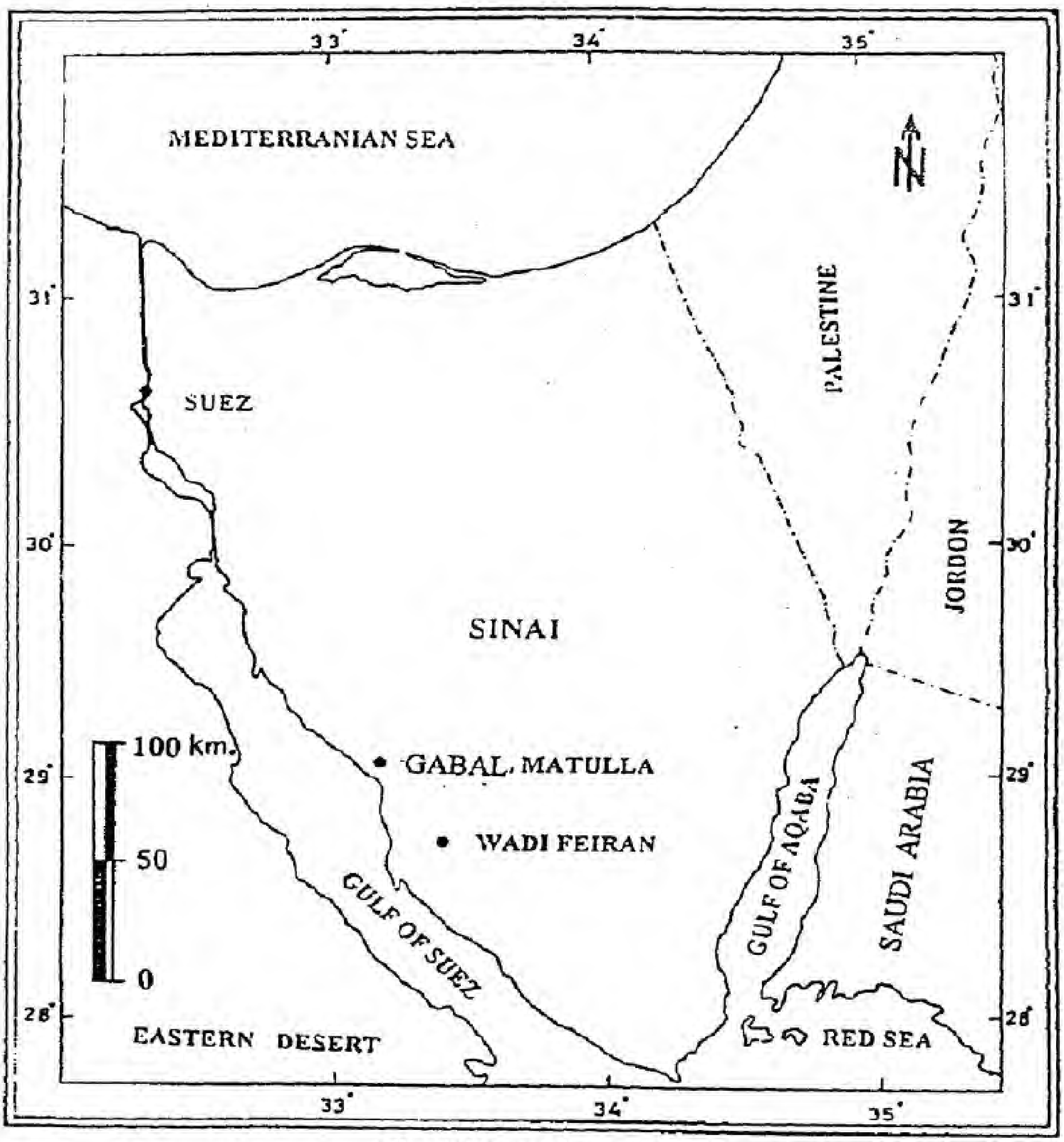

Fig. (1) Location map.

Some selected planktonic foraminiferal and calcareous nannofossil species are illustrated on plates of Figs (8,9).

PLANKTONIC FORAMINIFERAL ZONATION

The study of the planktonic foraminifera in the measured sections revealed three zones in the Maastrichtian, seven zones of Paleocene and three zones of Early Eocene. These biozones are discussed herein from base to top. Abbreviations used are : FO = First Occurrence, LO = Last Occurrence..

Zones of Maastrichtian

1. Globotruncana aegyptiaca Zone

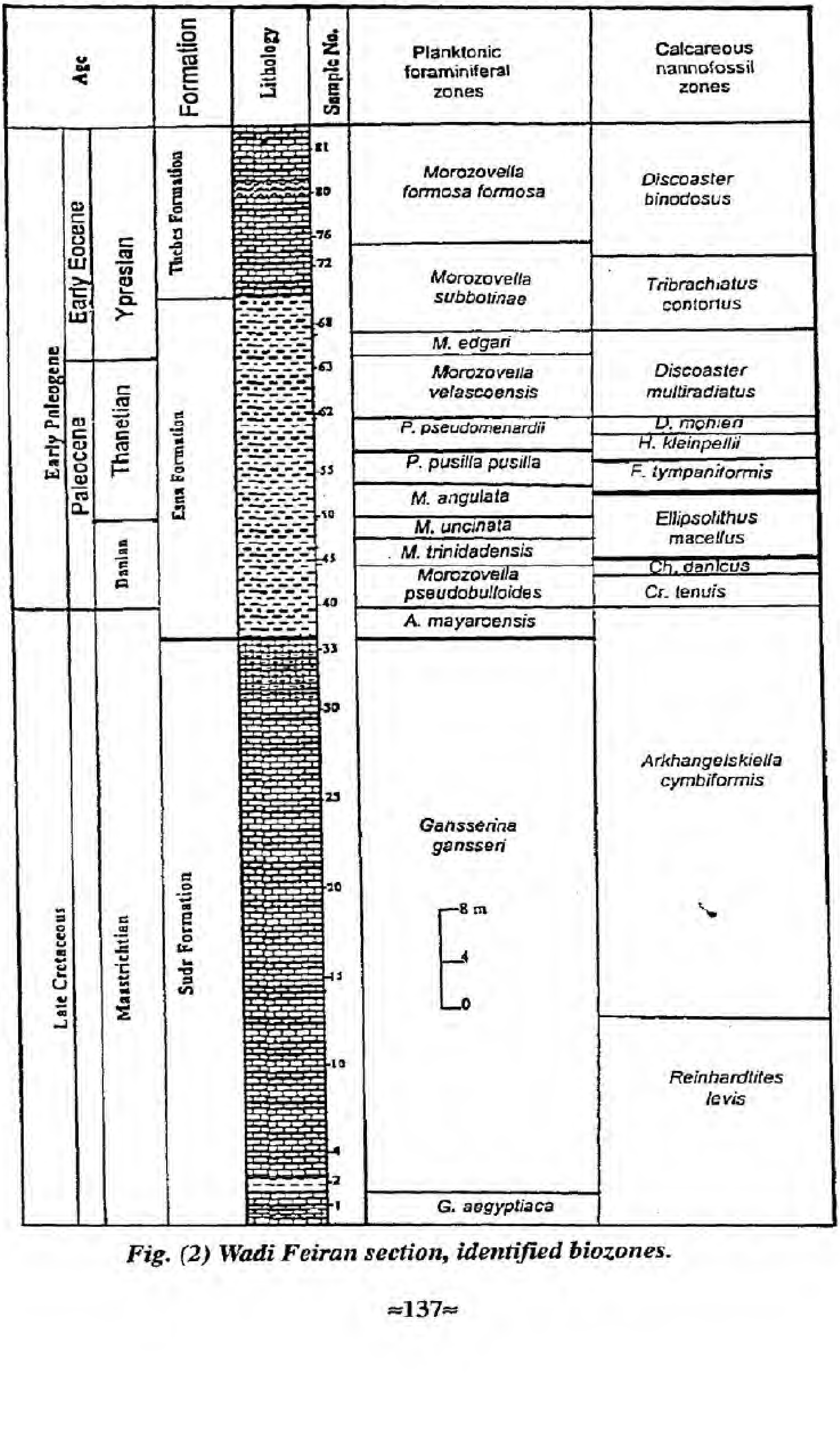

Fig. (2) Wadi Feiran section, identified biozones.

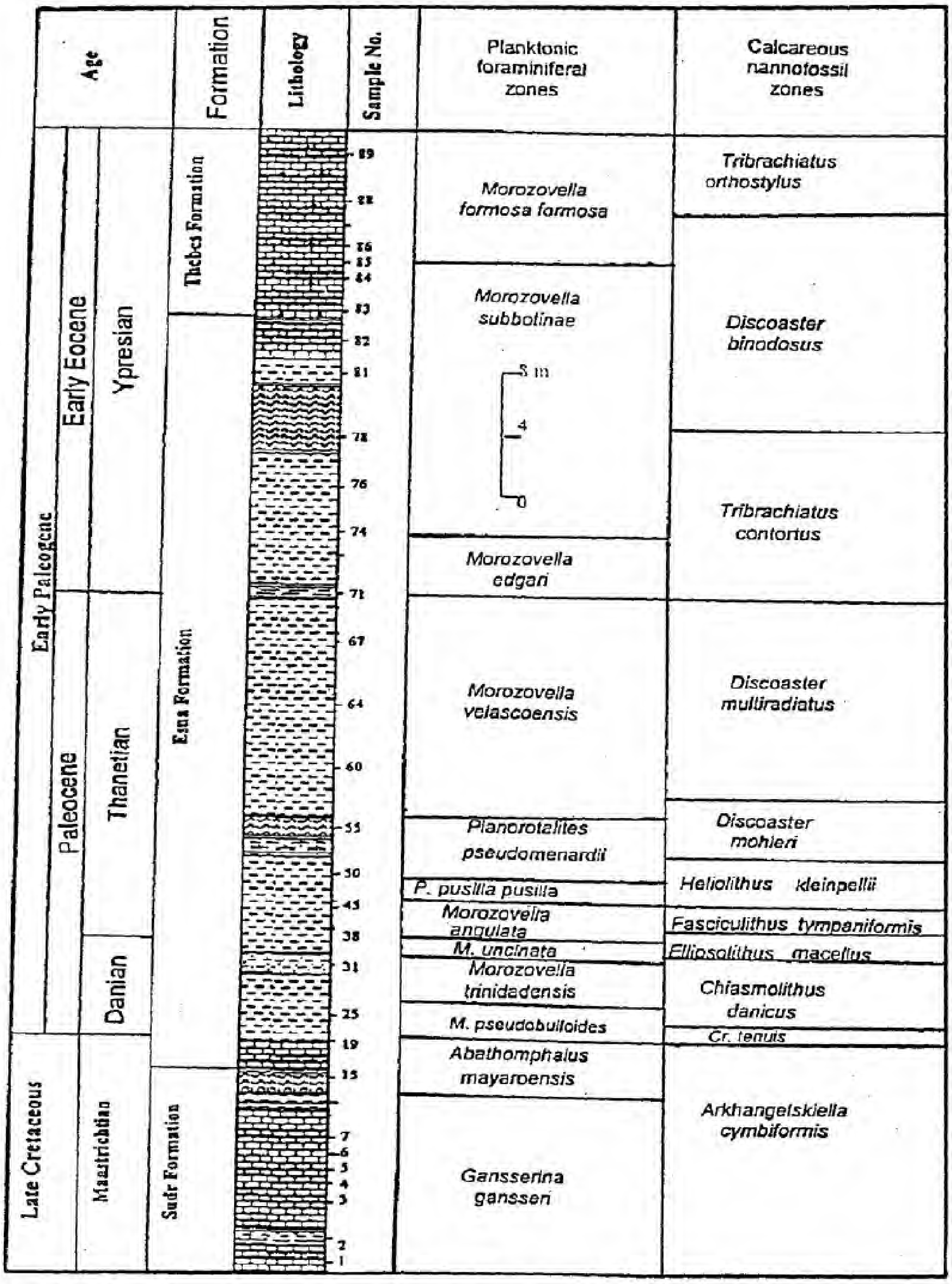

Fig. (3) G. Matulla section identified biozones.

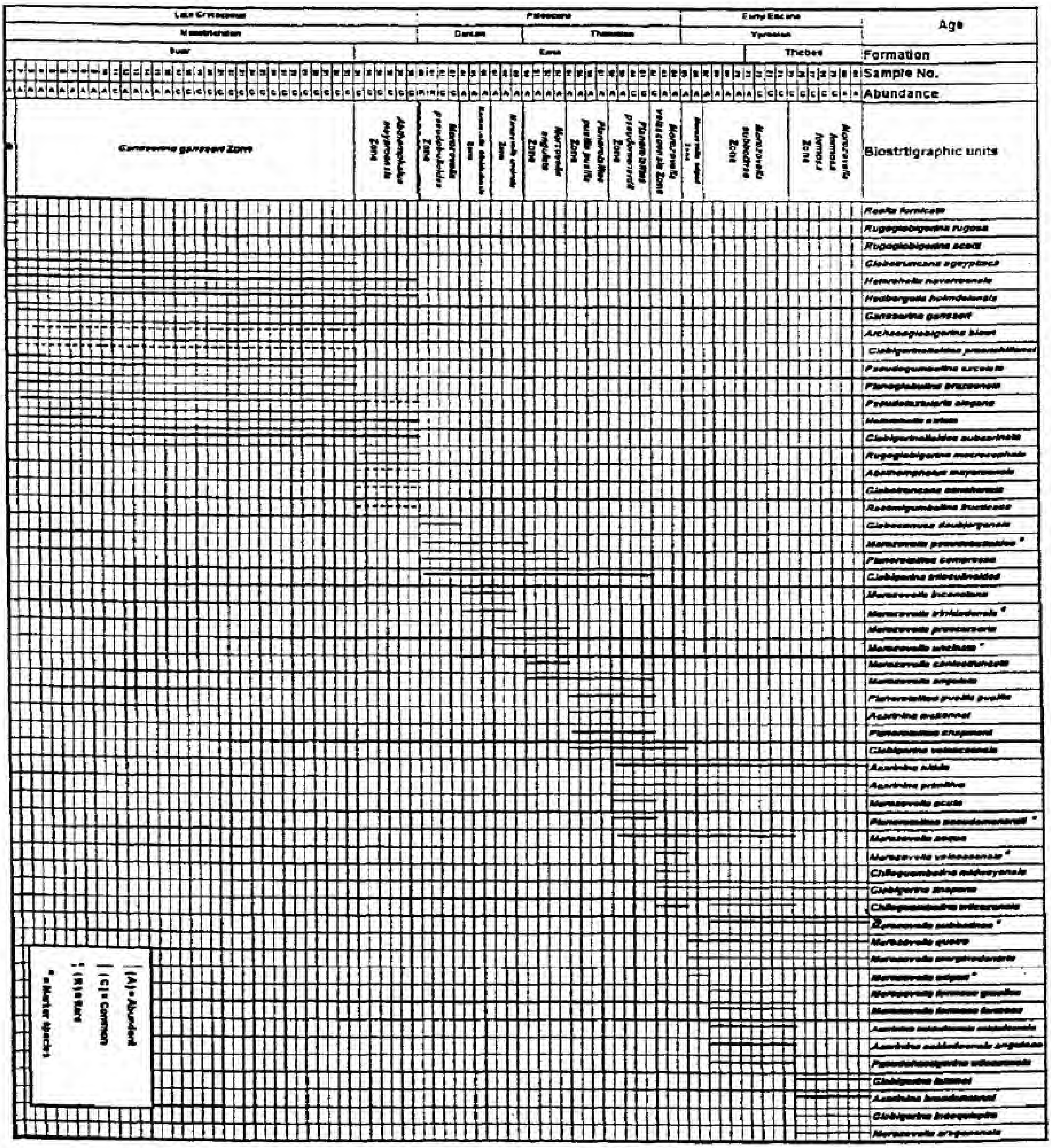

Fig. (4) Stratigraphic Distribution of The Planktonic Foraminiferal Species Recongnized in The Wadi Feiran Section.

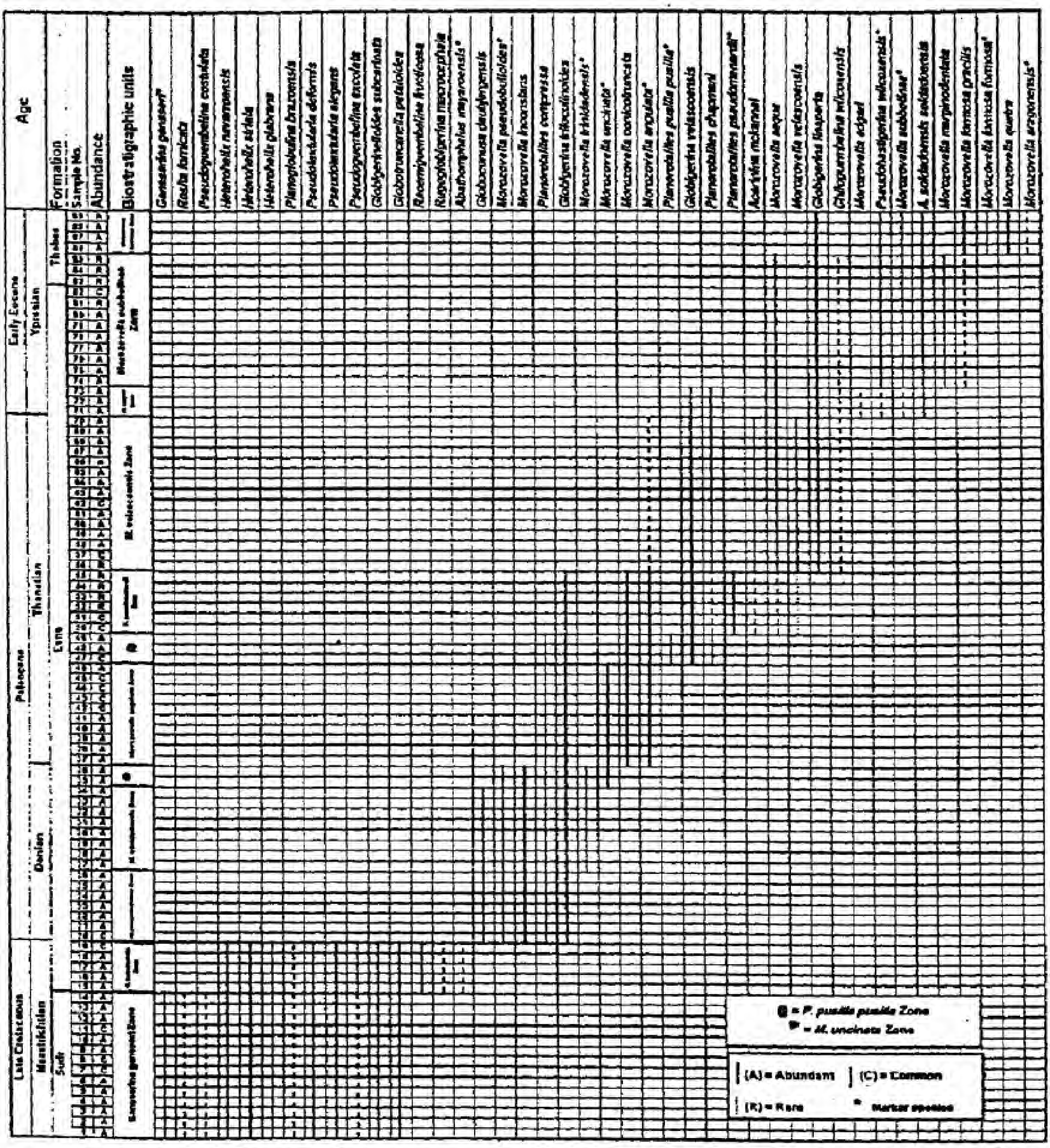

Fig. (5) Stratigraphic distribution of planktonic foraminiferal species recognized in the Gabal Matulla section

Sample NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Age	Late Cretaceous																																						
	Early Maastrichtian												Late Maastrichtian																										
Formation	Sudr																																	Esna					
Abundance	F	A	A	F	F	F	F	C	A	C	C	A	A	A	C	E	A	A	A	F	F	A	A	F	C	F	A	C	C	C	C	C	F	F	F	F	F	F	F
Preservation	M	G	G	M	M	M	M	M	G	M	M	G	G	G	M	M	M	M	M	M	M	M	M	M	M	M	G	G	M	G	G	G	M	M	M	M	M	M	M
Nannofossil zone	*Reinhardtites levis* Zone CC24												*Arkhangeleskiella cymbiformis* Zone CC25																										
Watznaueria barnesae	C	F	C	F	F	F	F	C	C	C	C	C	A	A	F	C	C	F	R	R	F	F	F	F	F	R	F	F	F	F	F	F	R	R	R	F	R	R	R
Arkhangeleskiella cymbiformis *	C	F	A	F	F	R	R	F	C	C	F	F	C	C	R	F	C	A	F	R	F	F	F	F	C	F	A	F	C	C	C	C	F	R	R	F	F	F	R
Eiffelithus turriseiffelii	R	R	C	R	R	R	R	C	C	F	R	R	C	F	R	R	F	F	R	R	F	R	F	F	R	R	F	F	R	R	F	R	R	R	R	R	R	R	R
Micula decussata	R	R	F	R	R	F	F	F	R	R	R	R	F	R	R	R	F	C	F	R	R	R	F	F	F	R	F	F	R	F	F	F	F	R	R	F	F	R	R
Cribrosphaerella ehrenbergii	F	F	F	R	R	F	R	F	F	R	R	F	R	F	R	R	F	F	F	R	P	P	R	R	R	R	R	F	R	F	R	R	R	R	R	F	F	F	P
Micula concava	F	R	R	R	R	R	R	R	R	R		R			P	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Thoracosphaera operculata	R	R	R	R	R	R	R	F	R	R	R	R	R	R	R	R	R	F	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Eiffelithus gorkae		R	R	R	R	R	R	R	R							R	R		R	R	F	R	R	R	R	R			R	R	R	R							
Cyclagelosphaera reinhardtii	F	F	R	R	R	R	R		F	R	R	R	R	R	R	R	R	R	R	R		R	R	R	R	R													R
Zygolithus crux		R																				R		R															
Prediscosphaera grandis		R																										R						R	R		R		
Lithraphidites carniolensis		R			R	R	R	R	R		R	R	R	R	R		R	R	R	R	R	R	F	F	R	R	R	P	P	F	R	R	R	R		P	R	R	
Lucianorhabdus cayeuxii					R	R	R	R							P	P	R	R	R		R			R	P	P									P	P	P	P	P
Rhagodiscus angustus			R																																				
Microrhabdulus decoratus				R			R	F	F	P	R	F	R	R	R	R	R	R	R	R	R	R		R	R		R	R	R	R	R	R	R	P	P	P	P	P	P
Microrhabdulus stradneri						R			F		R	R	R	R								R					R	R		R			R						
Placozygus sigmoides							R		R		R	R	R	R	R	R	R	R	R	R		R		R	R	R										R	R	R	R
Cribrocorona gallica							R										R	R				R	R	R	R			R	R	R	R	R		R				R	
Manivitella pemmatoidea									R																														
Zeugrhabdotus pesudanthophorus									R		R	R	R	R		R	R	R			R					R	P	P	P	R	R	R	P	P	P	P	P	P	P
Prediscosphaera cretacea									R	R	R		R		P	P	P	P	R	R	P	R	R	R	R	R	P	P	P	R	F	R	R	R	R	R	P	R	R
Kamptnerius punctatus												R					R						R								R								
Kamptnerius magnificus												R					R						R								R	F							P
Reinhardtites levis *												R																											
Reinhardtites anthophorus												R																											
Cretarhabdus conicus														R	P	P	P	P																					
Cribrosphaerella daniae															R		R	R			R																		
Lithraphidites quadratus																R	R			R		R	F	P	P														
Braarudosphaera bigelowii																				P	P	P	P	P	P	P													
Chiastozygus amphipons																								R												R	R	R	
Gaukolithus diplogrammus																									R	R													
Prediscosphaera stoveri																											R				R	R	R						
Prediscosphaera spinosa																											R						R						
Micula murus *																																R	R	R	R	R	R	R	R
Ahmuellerella octoradiata																																R							
Chiastozygus amphipons																																				R	R	R	

A: Abundant
C: Common
F: Frequent
R:Rare

*: Marker species
G: Good
M: Moderate
P: Poor

Fig. (6) Stratigraphic distribution of the calcareous nannofossil species recognized in the Wadi Feiran section.

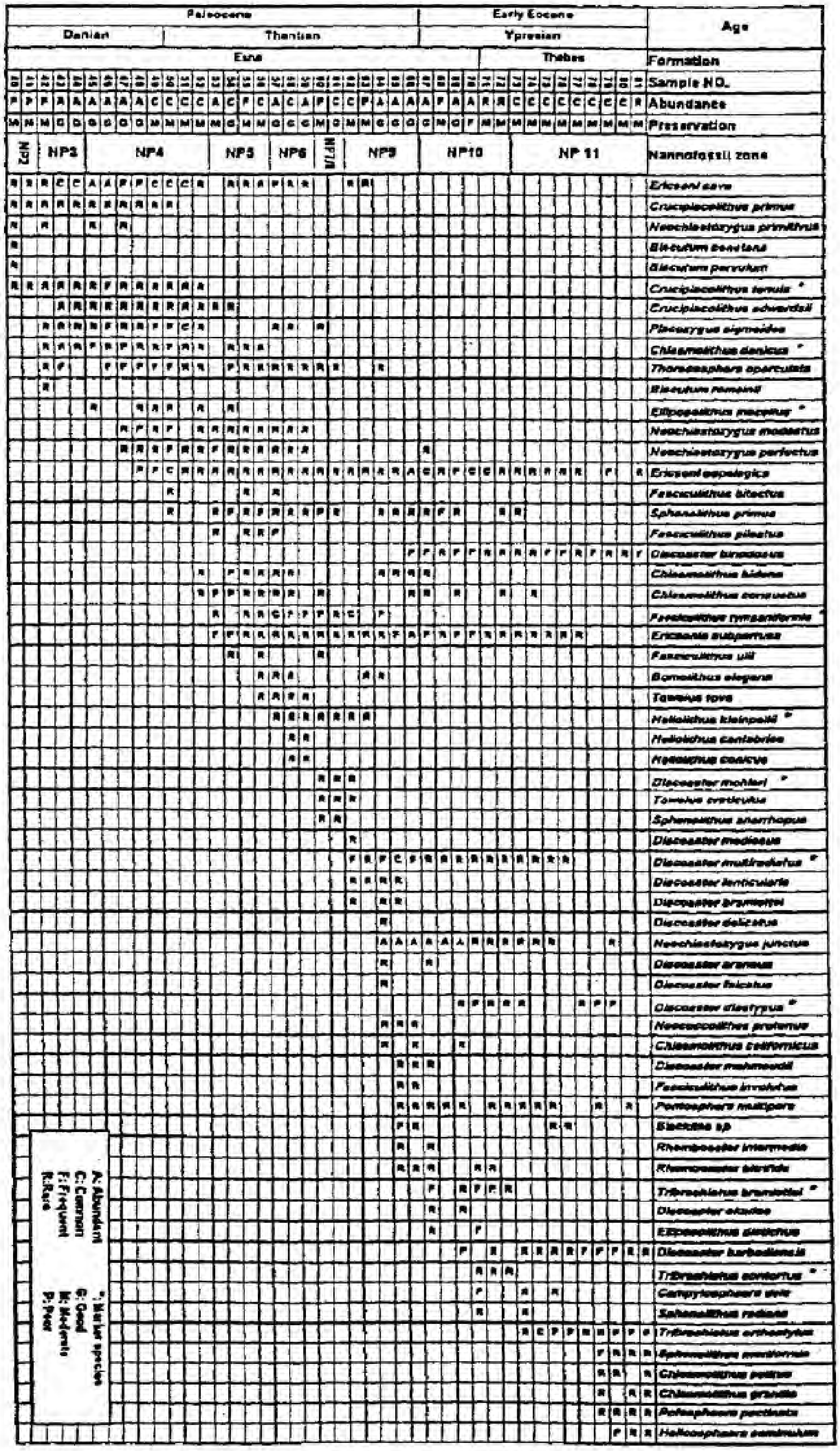

Fig. (6) Continued

Late Cretaceous																			Age
Late Maastrichtian																			
Sudr														Esna					Formation
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Sample No.
A	A	F	C	A	C	C	R	A	R	C	A	A	C	A	C	C	C	C	Abundance
M	M	M	G	G	G	G	P	M	R	G	M	G	G	G	G	G	G	G	Preservation
Arkhangeleskilla cymbiformis (CC 25)																			Nannofossil zone
F	F	F	C	C	C	C	R	R	P	F	F	C	A	A	C	C	C	C	*Watznaueria bamasae*
F	F	F	C	C	C	C	R	C	R	C	F	C	C	C	F	F	F	F	*Arkhangelaskiella cymbiformis* *
F	F	F	C	C	C	C	R	P	R	F	R	R	R	R	F	C	C	C	*Eiffellithus turriseiffelii*
R	R	R	P	P														R	*Lucianorhabdus cayeuxii*
R	R	R	P	P	P	P	R	R	R	R	R	R	R	F	F	F	F	F	*Cribrosphaerrella ehrenbergii*
P	R	R	P	P				R				R	R	F	F	F	F	F	*Microhabdulus decoratus*
C	C	P	P	P	P	P	P	F	R	C	F	C	C	A	C	C	C	C	*Micula decussata*
R	R	R	R	R	R	R		R				R	R	R		R	F	F	*Lithraphidites quadratus*
P	P	P			P			R			R			R			R	R	*Braarudosphera baglowii*
P	P	P	P	P	P	P							R	R		R	R	R	*prediscosphaera cretacea*
R	P	P	P	P	P													R	*Eiffelithus grokae*
F	C	R	F	F	F	F							R	C	C	C	C	C	*Micula concava*
P	P	R	R	R	R							R				R			*Rhagediscus angustus*
R	R	R	R	R	R	R				R		R	R	R		R	R	R	*Lithraphidites carniolensis*
			R	R	R	R										R	R		*Zygodiscus spiralis*
			R	R	R	R		R		R	R	R	R	F		R	R		*Cyclagelosphaera reinhardtii*
				R	R	R	R	R	R		R	R	R	F	F	R	R	R	*Thoracosphaera operculata*
				R	R	R	R		R				R	R			R	R	*Placozygus sigmoides*
					R	R												R	*kamptnerius magnificus*
								R		R		R	R	R		R			*Cribrocorona gallica*
								C	R	F	R	C	C	A	C	C	F	F	*Micula murus* *
										R		R		R	R	R		R	*Ahmuellerella octoradiata*
											R	R	R	F		R	R	R	*Cribrosphaerella daniae*
												R		R				R	*Rhagodiscus asper*
													R	R		R	R	R	*Prediscosphaera granidis*
													R	R				R	*Chiastozygus amphipons*
													R	R				R	*Chiastozygus litteranius*
																R		R	*Microrhabdulus stradneri*
																R	R	R	*Biscutum constans*
																		R	*Zeugrhabdotus pseudanthophours*
																		R	*Zeugrhabdotus embergeri*
																		R	*Zygolithus crux*
																		R	*Creratolithoides kamptneri*

A:= Abundant *= Marker species
C:=Common G = Good
F:=Frequent M := Moderate
R:= Rare P :=Poor

Fig. (7) Stratigraphic distribution of the calcareous nannofossil species recognized in Gabal Matualla section

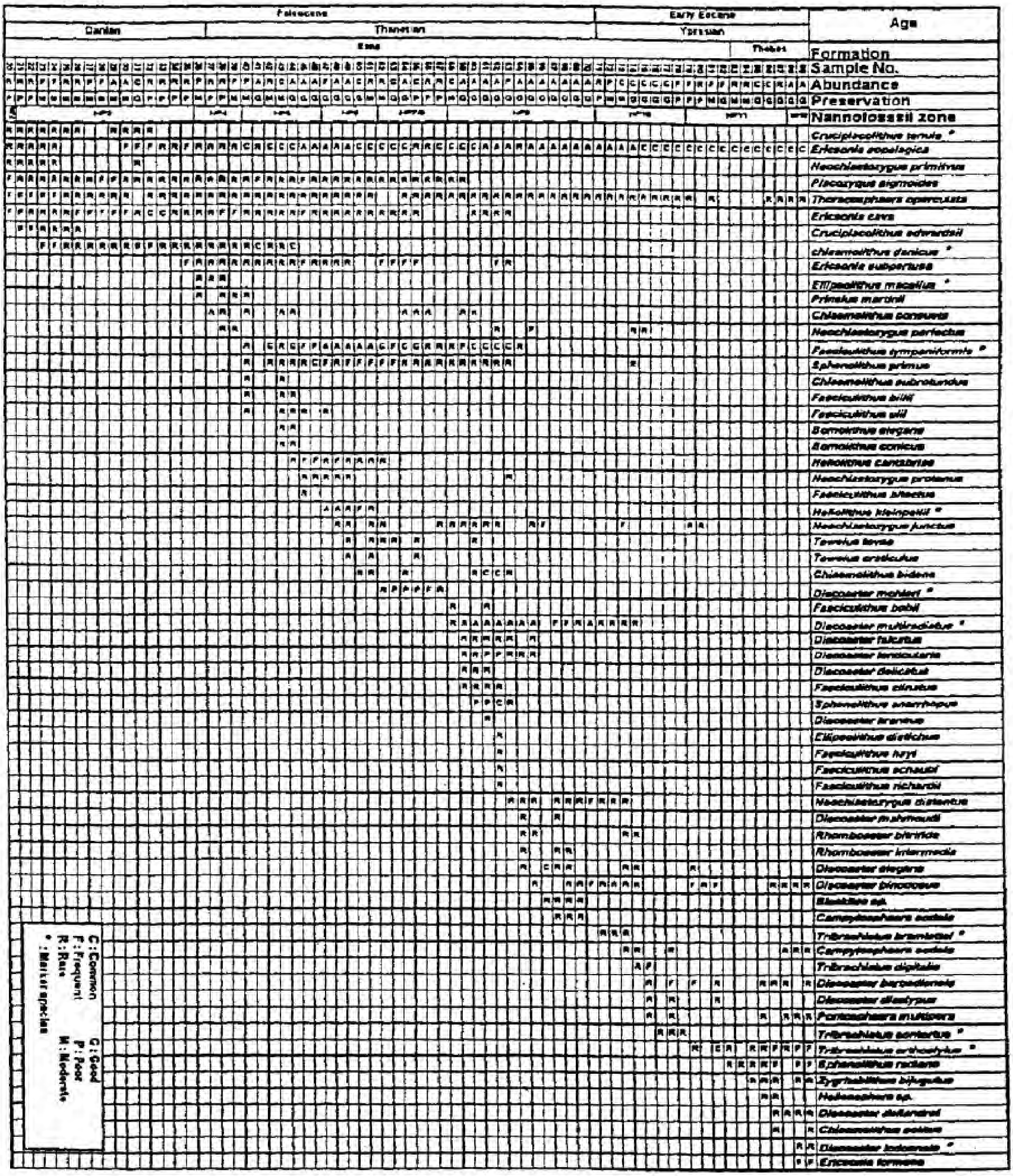

Fig. (7) Continued

This zone includes the interval from the FO of *Globotruncana aegyptiaca* to the FO of *Gansserina gansseri*.

In addition to the marker species, the following species are recorded in this zone : *Rosita fornicata, Rugoglobigerina rugosa, Rugoglobigerina scotti, Heterohelix navarroensis and Hedbergella holmdelensis*. This zone is the oldest identified zone in the studied sections and is recorded only in Wadi Feiran section with thickness of about 2 m within the Sudr Formation.

2. Gansserina gansseri Zone

This zone comprises the interval from the FO of *Gansserina gansseri* to the FO of *Abathomphalus mayaroensis*.

The Gansserina gansseri Zone in the investigated area is characterized by the presence of *Globotruncana aegyptiaca, Gansserina gansseri, Pseudotextularia* elegans, *Archaeoglobigerina blowi, Globigerinelloides praeriehillensis, Pseudoguembelina excolata, Planoglobulina brazoensis, Globigerinelloides subcarinata, Heterohelix striata, Heterohelix navarroensis, Heterohelix glabrans, Globotruncanella petaloidea, Pseudotextularia deformis, Pseudoguembelina costulata, Hedbergella holmdelensis and Rosita fornicata.*

This zone is recorded in the Sudr Formation at Wadi Feiran and Gabal Matulla sections with thickness of about 54 m and 16 m respectively.

This zone is corresponded to the *Gansserina gansseri* Zone of Robaszynski et al. (1984), Caron (1985) and Faris (1985).

3. *Abathomphalus mayaroensis* Zone

It includes the interval of total range of *Abathomphalus mayaroensis*.
In the studied sections the Abathomphalus mayaroensis Zone is characterized by the following species : *Racemiguembelina fructicosa, Globigerinelloides subcarinata, Rugoglobigerina macrocephala*, Hedbergella holmdelensis, Heterohelix navarroensis, *Heterohelix striata, Pseudotextularia elegans, Abathomphalus mayaroensis, Globotruncana esnehensis, Heterohelix glabrans, Planoglobulina brazoensis, Pseudotextularia deformis, Pseudoguembelina excolata, and Globotruncanella petaloidea.*

This zone is recorded in the lower part of the Esna Formation in the sections of Wadi Feiran (5 m thick) and Gabal Matulla (2 m thick).

It is equivalent to that of Robaszynski et al. (1984) and Faris (1985).

Zones of Paleocene

1. Morozovella pseudobulloides Zone

The base of the zone is defined by the FO of *Morozovella pseudobulloides* and its top by the FO of *Morozovella trinidadensis*.

The characteristic assemblage of this zone includes : *Globoconusa daubjergensis, Morozovella pseudobulloides, Morozovella inconstans, Planorotalites compressa and Globigerina triloculinoides.*

The M. pseudobulloides zone is recorded in the Esna Formation at Wadi Feiran (2 m thick) and Gabal Matulla (3 m thick).

The present zone is matched with the *Subbotina triloculinoides* subzone (P1b) of Berggren & Miller (1988) and the Morozovella pseudobulloides zone of El-Deeb & El-Gammal (1994).

2. Morozovella trinidadensis Zone

This zone is defined as the interval between the FO of *Morozovella trinidadensis* to the FO of *Morozovella uncinata*.

The *M. trinidadensis* Zone is characterized by the following species : *Globoconusa daubjergensis*, *Morozovella pseudobulloides*, *Morozovella inconstans*, *Morozovella trinidadensis*, *Planorotalites compressa* and *Globigerina triloculinoides*.

The *M. trinidadensis* Zone is recognized in the Esna Formation at Wadi Feiran (2 m thick) and Gabal Matulla (4 m thick).

It coincides with the *Morozovella trinidadensis* Zone defined by Toumarkine & Luterbacher (1985) and Faris et al. (1999).

3. Morozovella uncinata Zone

The *Morozovella uncinata* Zone includes the interval from FO of *Morozovella uncinata* to FO of *Morozovella angulata*.

In addition to the marker species this zone includes : *Morozovella pseudobulloides*, *Morozovella inconstans*, *Morozovella trinidadensis*, *Morozovella praecursoria*, *Planorotalites compressa* and *Globigerina triloculinoides*.

This zone is recorded in the Esna Formation at Wadi Feiran and Gabal Matulla with thickness at about 2 m, 1 m, respectively.

The *Morozovella uncinata* Zone is correlated with the *Morozovella uncinata-Igorina spiralis* Zone(P 2) of Berggren &Miller (1988) and that of El-Deeb & El-Gammal (1994).

4. Morozovella angulata Zone

This zone is defined as the interval from FO of *Morozovella angulata* to FO of *Planorotalites pusilla pusilla*.

The *Morozovella angulata* Zone is characterized by the following planktonic foraminiferal assemblage : *Morozovella praecursoria*, *Morozovella uncinata*, *Morozovella conicotruncata*, *Morozovella angulata*, *Planorotalites compressa* and *Globigerina triloculinoides*.

The *M. angulata* Zone is recorded from the Esna Formation at Wadi Feiran (4 m thick) and Gabal Matulla sections (6 m thick).

It is equivalent to the *Morozovella angulata* Zone of Toumarkine & Luterbacher (1985) and El-Deeb and El-Gammal (1994).

5. Planorotalites pusilla pusilla Zone

This zone is defined as the interval from FO of *Planorotalites pusilla pusilla* to the FO of *Planorotalites pseudomenardii*.

Besides the marker species this zone includes : *Morozovella conicotruncata*, *Morozovella angulata*, *Planorotalites champani*, *Globigerina triloculinoides* and *Globigerina velascoensis*.

This zone is recorded in the Esna Formation from Wadi Feiran and Gabal Matulla sections with the same thickness of about 1 m thick.

It is equivalent to the upper subzone at *Morozovella angulata-Igorina pusilla* (P3b) of Berggren & Miller (1988) .

6. Planorotalites pseudomenardii Zone

This zone is characterized by the total range of the nominate species.

The *Planorotalites pseudomenardii* Zone includes the same species recorded in the previous zone in addition to *Morozovella acuta, Morozovella aequa, Morozovella velascoensis, Planorotalites pseudomenardii, Acarinina mckannai, Acarinina nitida* and *Acarinina primitiva.*

This zone is recorded in the Esna Formation in Wadi Feiran and Gabal Matulla sections with thickness of about 4 m and 2 m respectively.

The *Planorotalites pseudomenardii* Zone correlates with that of Toumarkine & Luterbacher (1985), Berggren & Miller (1988) and Faris et al. (1999).

7. Morozovella velascoensis Zone

The base of the zone is defined by LO *Planorotalites pseudomenardii* and the top by the LO of *Morozovella velascoensis.*

This zone is characterized by the first appearance of several species such as *Globigerina linaperta, Chiloguemblina midwayensis* and *Chiloguemblina wilcoxensis* beside the *Morozovella velascoensis.*

This zone is recorded at the Esna Formation in Wadi Feiran (4 m thick) and Gabal Matulla (16 m thick) sections .

The *Morozovella velascoensis* is equivalent to that described by Toumarkine & Luterbacher (1985) and Aref et al. (1988).

Zones of Eocene

1. Morozovella edgari Zone

The zone is defined as the interval between LO of *Morozovella velascoensis* and FO of *Morozovella edgari.*

The *Morozovella edgari* Zone is characterized by the following species : *Morozovella aequa, Morozovella edgari, Morozovella formosa gracilis, Morozovella subbotinae, Morozovella quetra, Planorotalites champani, Globigerina velascoensis, Globigerina linaperta, Acarinina nitida, Acarinina primitiva, Pseudohastigerina wilcoxensis* and *Chiloguemblina wilcoxensis.*

This zone is well defined from the Esna Formation at Wadi Feiran and Gabal Matulla sections with thickness of about 1 m and 4 m respectively.

The *Morozovella edgari* Zone corresponds to the lower part of the subzone (P6b) of Berggren & Miller (1988) and with *Morozovella edgari* Zone of Faris et al. (1999).

2. Morozovella subbotinae Zone

The *Morozovella subbotinae* Zone includes the interval between LO of *Morozovella edgari* and FO of *Morozovella aragonensis*.

This zone is marked by the following species : *Morozovella aequa, Morozovella formosa gracilis, Morozovella subbotinae, Morozovella quetra, Morozovella marginodentata, Globigerina linaperta, Acarinina nitida, Acarinina primitiva, Acarinina soldadoensis soldadoensis, Acarinina soldadoensis angulosa, Chiloguemblina wilcoxensis* and *Pseudohastigrina wilcoxensis*.

In the studied sections this zone is well defined from the uppermost part of the Esna Formation and the lower part of the Thebes Formation with variable thickness at Wadi Feiran (9 m thick) and G. Matulla (20 m thick) .

This zone coincides with the upper part (P6b) and (P6c) subzones of Berggren & Miller (1988) and *Morozovella subbotinae* Zone of Faris et al. (1999).

3. Morozovella formosa formosa Zone

The base of the zone is defined by the FO of *Morozovella aragonensis* and its top by the FO of *Acarinina pentacamerata*.

The *Morozovella formosa formosa* Zone is characterized by the following species : *Morozovella aragonensis, Morozovella quetra, Morozovella marginodentata, Globigerina linaperta, Globigerina lozanoi, Globigerina inaequispira, Acarinina nitida, Acarinina primitiva, Acarinina soldadoensis soldadoensis, Acarinina soldadoensis angulosa, Acarinina broedermanni,* and *Planorotalites wilcoxensis*.

This zone is well defined from Thebes Formation at Wadi Feiran and Gabal Matulla sections with thickness of about 8 m and 12 m respectively.

The *Morozovella formosa formosa* Zone is equivalent to that of Toumarkine & Luterbacher (1985) and Faris et al. (1985).

CALCAREOUS NANNOFOSSIL ZONATION

Zones of Maastrichtian

1. Reinhardtites levis Zone (CC24)

The *Reinhardtites levis* Zone includes the interval from the LO of *Tranolithus phacelosus* to the LO of *Reinhardtites levis*.

In the present study, the *R. levis* Zone includes the interval of the total range of *Reinhardtites levis*.

The *Reinhardtites levis* Zone is recorded in the Sudr Formation at Wadi Feiran section and it attains a thickness of about 19 m.

The *Reinhardtites levis* Zone includes diversified calcareous nannofossil typical of the Maastrichtian, *Watznaueria barnesae, Arkhangeleskiella cymbiformis, Eiffelithus turriseiffelii, Cribrosphaerrella ehrenbergii, Microrhabdulus decoratus, Micula decussata, Eiffelithus gorkae, Micula concava, Prediscosphaera grandis, Lithraphidites carniolensis, Cyclagelosphaera reinhardtii, Cribrocorona gallica, Lucianorhabdus cayeuxi, Rhagodiscus angustus, Zygolithus crux, Microrhabdulus stradneri, Placozygus sigmoides, Manivitella pemmatoidea, Zeugrhabdotus*

pseudanthophorus, Prediscosphaera cretacea, Reinhardtites anthophorus, Reinhardtites levis, Kamptnerius magnificus and *Kamptnerius punctutus*.

In Egypt, Arafa (1991) recorded the *Reinhardtites levis* Zone in the lower part of Sudr Formation at Gabal Nazzazat.

Sissingh (1977) mentioned that the LO of *R. levis* virtually coincides with a distinct and interregional increase in number of large *Arkhangelskiella* representatives.

2. Arkhangelskiella cymbiformis Zone (CC25)

The zone is defined as the interval between the LO of *Reinhardtites levis* to the FO of *Nephrolithus frequens*.

There are several definitions attached to the name *A. cymbiformis* Zone. Perch-Nielsen (1972) defined it from the LO of *R. anthophorus* (meaning the form now described as *R. levis*) to the FO of *M. murus* or *N. frequens*. In the present study, the *A. cymbiformis* Zone includes the interval from the last occurrence of *R. levis* to the first occurrence of *Cr. tenuis*. Sissingh (1977) suggested a subdivision of CC25 by the FO of *Arkhangelskiella cymbiformis* and the FO *Lithraphidites quadratus*. The *Arkhangelskiella cymbiformis* Zone is recorded from the Sudr Formation and lower part of the Esna Formation at Wadi Feiran and from the Sudr Formation at Gabal Matulla section with thickness 45 m and 8 m respectively.

The *Arkhangelskiella cymbiformis* Zone is characterized by the same assemblage of the previous zone in addition to the following taxa : *Cribrosphaerella daniae, Lithraphidites quadratus, Braarudosphaera bigelowii, Chiastozygus amphipons, Glaukolithus diplogrammus, Prediscospharea stoveri, Prediscospharea spinosa, Ahmuellerella octoradiata, Chiastozygus litterarius, Ceratolithoides kamptneri, Cretarhabdus conicus, Rhagodiscus asper* and *Micula murus*.

Zones of Paleocene

1. Cruciplacolithus tenuis Zone (NP2)

This zone comprises the interval from the FO of *Cruciplacolithus tenuis* to the FO of *Chiasmolithus danicus*.

This zone was first recognized by Hay & Mohler (1967). The upper boundary of this zone is delineated at the first occurrence of *Fasciculithus tympaniformis*. The zone is later emended by Martini (1970) and it embraces the interval from the first occurrence of *Cruciplacolithus tenuis* to the first occurrence of *Chiasmolithus danicus*. It is recorded in the El-Kef section of Tunisia by Haq & Aubry (1981) and in Azerbajan by Reyhan (1992).

In the present work, the *Cruciplacolithus tenuis* Zone is recorded from the lower part of the Esna Formation and it represents the lowermost Paleocene nannofossil zone in Wadi Feiran and Gabal Mattulla sections with thickness of about 1.5 m, 0.5 m, respectively. The *Cruciplacolithus tenuis* Zone is characterized by the following calcareous nannofossils assemblage: *Ericsonia cava, Cruciplacolithus primus, Neochiastozygus primitivus, Biscutum constans, Biscutum parvulum, Cruciplacolithus tenuis, Ericsonia eopelagica; Placozygus sigmoides* and *Thoracosphera operculata* in addition to some reworking Cretaceous forms.

In Egypt this Zone was recorded by Kerdany (1970), Sadek & Teleb (1978), Faris (1994), and Faris et al. (1999) from different localities.

2. Chiasmolithus danicus Zone (NP3)

The *Chiasmolithus danicus* Zone is defined as the interval from the FO of *Chiasmolithus danicus* to the FO of *Ellipsolithus macellus*.

This zone was first proposed by Martini (1970). It is correlated with the *Chiasmolithus danicus* Zone (CP2) of Okada & Bukry (1980).

In the present work, the *Chiasmolithus danicus* Zone is recorded from the Esna Formation in Wadi Feiran (2 m) and Gabal Matulla (8 m) sections. The *Chiasmolithus danicus* Zone is characterized by the same assemblage of the previous zone in addition to *Chiasmolithus danicus*.

In Egypt this zone has been recorded at Gabal Um El-Ghanayem section (Kharga Oasis) by Sadek & Teleb (1978). It was also recorded by Faris (1994) in some localities.

3. Ellipsolithus macellus Zone (NP4)

This zone is defined as the interval from the FO of *Ellipsolithus macellus* to FO of *Fasciculithus tympaniformis*.

In the present study the *Ellipsolithus macellus* Zone (NP4) is recorded from the Esna Formation at Wadi Feiran (8 m thick) and Gabal Matulla (2 m thick) sections. Of the most interesting event is the diversification of *Fasciculithus bitectus, F. billii, F. ulii* in the upper part of Zone NP4 and close to the Danian/Thanetian boundary, as suggested by Pospichal and Wise (1990).

This zone is comparable with the *Ellipsolithus macellus* Zone (CP3) of Okada & Bukry (1980). In Egypt this zone was recorded by Perch-Nielsen *et al.* (1978), Sadek & Teleb (1978), Bassiouni et al. (1990), and Faris (1994) from many localities.

4. Fasciculithus tympaniformis Zone (NP5)

This zone is defined as the interval from the FO of *Fasciculithus tympaniformis* to the FO of *Heliolithus kleinpelli*.

In the present study the *Fasciculithus tympaniformis* Zone is recorded from the Esna Formation and it attains about 6 m thick at Wadi Feiran and 2 m thick at Gabal Matulla sections.

The *Fasciculithus tympaniformis* Zone is characterized by the following taxa in additon to the assemblage of the previous Zone : *Fasciculithus tympaniformis* and *Bomolithus elegans*. Perch-Nielsen (1979) correlated the base of NP5 Zone by the first occurrence of the *Neochiastozygus perfectus* which occurs above the first occurrence of *Chiasmolithus bidens*. Perch-Nielsen (op. cit.) subdivided this zone into two subzones due to the first occurrence of *Bomolithus elegans* and the subsequent first occurrence of *Heliolithus cantabriae*. In Egypt this Zone was recorded by Sadek & Teleb (1978) and Faris (1994) from different localities.

5. Heliolithus kleinpellii Zone (NP6)

The *Heliolithus kleinpellii* Zone includes the interval from the FO of *Heliolithus kleinpellii* to the FO of *Discoaster mohleri*.

This zone was originally recognized by Mohler & Hay (in Hay et al. 1967). It is defined as the interval from the first occurrence of the *Heliolithus kleinpelli* to the first occurrence of *Discoaster gemmeus*. Bukry & Percival (1971) mentioned that the *Discoaster gemmeus* is not

found in Paleocene but it is found in the Eocene. So, this zone is defined by Bukry (1973) as the interval from the first occurrence of *Heliolithus kleinpellii* to the first occurrence of *Discoaster mohleri*. This zone is equivalent to the *Heliolithus kleinpellii* Zone (CP5) of Okada & Bukry (1980).

In the studied area this zone is defined within the Esna Formation in Wadi Feiran and Gabal Matulla sections with thickness of about 1 m and 2 m respectively.

6. Discoaster mohleri Zone (NP7/8)

The base of *Discoaster mohleri* Zone is defined by the FO of *Discoaster mohleri* and its top is recognized by the FO of *Discoaster multiradiatus*.

Hay (1964) placed the upper boundary of this zone at the first occurrence of the *Heliolithus riedelii* (zonal marker of NP8). Since the *Heliolithus riedelii* is rare or completely absent at many land sections as well as DSDP sites, many authors tend to use the NP7/NP8 interval as a combined zone. Bukry (1973) introduced the *Discoaster nobilis* Zone which was more or less equivalent to the *Heliolithus riedelii* Zone, but in many sections the first occurrence of *Discoaster nobilis* has the same level as *Discoaster multiradiatus*. In several sections *Discoaster mohleri* is scarce or absent, therefore, the FO of *Sphenolithus anarrohopus* was used by Varol (1989) as a substitute marker to delineate the base of NP7/NP8 Zone.

In the present work this zone is recorded from the Esna Formation at Wadi Feiran and Gabal Matulla sections with thickness of about 1 m and 2 m respectively. This zone is characterized by the same taxa as the Zone NP6, in addition to: *Discoaster mohleri* and *Sphenolithus anarrhopus*. In Egypt this zone was recorded by many authors : Perch-Nielsen *et al.* (1978), , Bassiouni *et al.* (1990); Faris (1994)and Faris *et al.* (1999); in different areas.

7. *Discoaster multiradiatus* Zone (NP9)

The lower limit of Zone NP9 (*D. multiradiatus*) is located by the FO of *Discoaster multiradiatus* and its upper limit can be traced by the FO of *Tribrachiatus bramlettei*.

This zone was first used by Bronnimann & Stradner (1960) in the Habana area, Cuba. The *Discoaster multiradiatus* Zone was described in more detail by Bramlette & Sullivan (1961). As defined by Mohler & Hay (in Hay *et al.* 1967) and adopted by Martini (1970), it embraces the interval from the first occurrence of *Discoaster multiradiatus* to the first occurrence of *Marthasterites bramlettei*.

This zone is equivalent to the *Discoaster multiradiatus* Zone (CP8) of Okada & Bukry (1980). In the present work the *D. multiradiatus* Zone is recorded from the Esna Formation at Wadi Feiran (2 m thick) and Gabal Matulla (18 m thick). The dominant taxa in this zone are : *Discoaster multiradiatus*, *Discoaster mediosus*, *Discoaster lenticularis*, *Neochiastozygus junctus*, *Discoaster falcatus*, *Neoccolithes protenus* and *Chiasmolithus californicus*. Other taxa first occur at the topmost Zone NP9, such as *D. okadae*, *D. mahmoudii*, *D. araneus*, *Pontosphaera multipora*, *Fasciculithus involutus*, *Blackite sp.*, *Rhomboaster intermedia* and *R. bitrifida*.

In Egypt this zone was recorded by Kerdany (1970); Perch-Nielsen *et al.* (1978); Sadek & Teleb (1978); Bassiouni *et al.* (1990); Faris (1991, 1994), and Faris *et al.* (1999).

Zones of Eocene

1. Tribrachiatus contortus Zone (NP10)

Is defined as the interval from the FO of *Tribrachiatus bromlettei* to LO of *Tribrachiatus contortus.*

This zone is recorded from the Esna Formation at Wadi Feiran and Gabal Matulla with thickness of about 7 m thick and 12 m thick. Several nannofossil species appear first in Zone NP10: *Tribrachiatus bramlettei, Discoaster barbadiensis, Tribrachiatus contortus, Tribrachiatus orthostylus*, and *Chiasmolithus grandis*. The NP10 Zone is equivalent to *Tribrachiatus contortus* Zone (CP9a) of Okada and Bukry (1980). They used the first occurrence of *Discoaster diastypus* and/or *Tribrachiatus contortus* to define the base of Early Eocene.

Martini (1970); Perch-Nielsen (1985) placed the Paleocene/Eocene boundary at the base of this zone. Aubry (1996) subdivided this zone into four subzones on the basis of new discovered species (*Tribrachiatus digitalis*).

T. digitalis first appears within the lower part of zone NP10 in the studied sections. This species has a broad geographic distribution in Egypt Dababiya section, near Esna (Aubry *et al.* 1999). It is also recorded in the DSDP site 550, North Atlantic (Aubry 1996).

In Egypt Zone NP10 is equivalent to the *Marthasterites contortus* Zone of Kerdany (1970); El-Dawoody & Barakat (1972), Perch-Nielsen *et al.* (1978) and Sadek & Teleb (1978). It is also relevant to that of Faris (1991, 1994) and Faris *et al.* (1999) in some localities.

2. Discoaster binodosus Zone (NP11)

The *Discoaster binodosus* Zone includes the interval from LO of *Tribrachiatus contortus* to the LO of *Discoaster lodoensis*.

Hay & Mohler (1967) stated that the *Discoaster binodosus* Zone is recognizable in the Lower Ypresian. This Zone is equivalent to the *Discoaster binodosus* subzone (CP9b) of Okada & Bukry (1980). In the present work, NP11 Zone is recognized from the uppermost Esna Formation and lower part of the Thebes Formation at Wadi Feiran and Gabal Matulla sections with thickness of about 2 m and 16 m respectively. In addition to the nannofossils assemblages of the NP10 Zone the *D. binodosus* Zone is characterized by the following nannofossils taxa : *Sphenolithus moriformis, Chiasmolithus solitus, Helicosphaera seminulum, Sphenolithus radians* and *Zygodiscus bijugatus*.

In Egypt this zone was defined by many workers (e.g., Kerdany 1970; El-Dawoody & Barakat 1972; Faris 1991; and Faris *et al.* 1999).

3. Tribrachiatus orthostylus Zone (NP12)

This zone is defined as the interval from FO of *Discoaster lodoensis* to LO of *Tribrachiatus orthostylus*.

This zone is recorded only from the Thebes Formation of Gabal Matulla section where is it 4m thick. Besides the assemblage of the previous zone, *Discoaster lodoensis, Ericsonia formosa* and *Discoaster deflandrei*, are recorded in this zone. In Egypt this zone was recorded by several authors (e.g. El-Dawoody & Barakat 1972, and Faris 1991).

STAGE BOUNDARIES

In the present study, three stage boundaries are identified according to the study of planktonic foraminifera and calcareous nannofossils content.

The Cretaceous/Paleogene (K/P) Boundary

In terms of calcareous nannofossil, the Cretaceous / Paleogene boundary is marked by nearly complete extinction of Mesozoic coccoliths. This event has been known and discussed extensively by Bramlette (1965). Numerous papers have dealt with the Cretaceous / Paleogene boundary in various parts of the world; Perch Nielsen (1981); Percival & Fischer (1977); Romein (1977); Jiang & Gartner (1986); Moshkovitz & Habib (1993) and Pospichal (1995).

In Egypt the *Micula prinsii* Zone was not recorded at Ghanima and Ain Amur sections, Kharga area, so it indicates the absence of the latest Maastrichtian. Also, the basal Danian is not known due to the absence of the *Markalius inversus* Zone, (Faris, 1985). Faris (1994), recognized the latest Maastrichtian *Micula prinsii* Zone at St. Paul section, southern Galala Plateau, Egypt. A detailed biostratigraphical study of the K/P boundary interval in 13 sections in several localites of Egypt has been carried out by Faris (1997), on the basis of calcareous nannofossils and the K/P boundary is marked by an increase in frequency of *Thoracosphaera operculata*, the disappearance of most Cretaceous taxa and by FO of newly evolved Early Paleocene species.

In the present study, the latest Maastrichtian is missing due to the absence of the calcareous nannofossil *Micula prinsii* Zone and the absence of the uppermost part of the planktonic foraminiferal *Abathomphalus mayaroensis* Zone. Also, the basal Danian is missing due to the absence of the calcareous nannofossil *Markalius inversus* Zone and the planktonic foraminiferal *Globigerina eugubina* Zone (Figs. 2,3).

Based on the calcareous nannofossils, several remarks on the K/P boundary in the investigated sections are observed : 1) The FO of Paleocene calcareous nannoplankton such as *Ericsonia cava*, *Cruciplacolithus primus*, *Neochiastozygus primitivus*, *Biscutum constans*, *Biscutum parvulum*, *Cruciplacolithus tenuis* and *Ericsonia eopelagica*; 2) The abrupt decrease in Maastrichtian taxa, and 3) The increased frequency of *Thoracosphaera operculata*. By means of planktonic foraminifera, the K/P boundary in the current study is delineated by the massive disappearance of the Late Maastrichtian assemblages which are replaced by new genera and species such as *Globoconusa daubjergensis*, *Morozovella pseudobboulloides*, *Globigerina triloculinoides*, *Morozovella inconstans* and *Planorotalites compressa*.

Early/Late Paleocene (Danian/Thanetian) Boundary

Vail *et al.* (1977), pointed out that the Danian stage is characterized by a particular high global stand of sea level that caused a marked transgression followed by a regression at the end of the stage. At Ghanima and Ain Amur sections of the Kharga area, Egypt, the Danian / Thanetian boundary is placed at the top of the *Morozovella uncinata* Zone (Faris 1985), but he could not define this boundary accurately by means of calcareous nannofossils.

Cherif & Ismail (1991) placed the Danian / Thanetian boundary at the *Morozovella uncinata* / *Morozovella angulata* zonal boundary of Esh El-Mellaha and Gharamul areas. Abdel Fattah & Molisso (1997) recorded a major regional unconformity at the Danian / Thanetian boundary in West Central Sinai, Egypt. Anan (1992) mentioned that a regression phase is responsible for the Early Paleocene / Late Paleocene hiatus as marked by the absence of *Morozovella angulata* and *Planorotalites pussilla pussilla* Zones at Abu Zenima, SW Sinai.

Faris *et al.* (1999) attributed the absence of *M. angulata* Zone in some selected areas in Central Egypt to the *Velascoensis* event of Strougo (1986). They could not define this boundary accurately by means of planktonic foraminifera due to the absence of *M. angulata* Zone.

In the present study the Danian/Thanetian boundary lies at the top of the *Morozovella uncinata* Zone and in the upper part of *Ellipsolithus macellus* (NP4) Zone in Wadi Matulla and Wadi Feiran sections (Figs.2,3).

Paleocene/Eocene (P/E) Boundary

In terms of calcareous nannofossils the Paleocene/Eocene boundary is usually drawn at the NP9 / NP10 zonal boundary which corresponds to the extinction level of the *Morozovella velascoensis*, in terms of planktonic foraminifera. Martini (1971) recognized the NP9 / NP10 zonal boundary by the FO of *Tribrachiatus bramlettei*. Traditionally, the P/E boundary is placed at the top of Zone NP9. However, the FO of *T. contortus* is recorded by most authors above P/E boundary (e.g. Hay & Mohler 1967; Okada & Bukry 1980 and many others).

Shackleton *et al.* (1984) found that several calcareous nannofossil genera disappeared near the end of the Paleocene, namely *Fasciculithus, Hornibrookina*, and *Placozygus*.

Bolli (1957) pointed out that the Paleocene/Eocene boundary lies at the NP9/NP10 zonal boundary and corresponds to the top of *Globorotalia velascoensis* Zone.

The P/E boundary has been defined at the LO of *M. veloscoensis* by different authors (e.g., Toumarkine & Luterbacher 1985; Berggren & Miller 1988). On the other hand, recent studies used the Benthic Extinction Event (BEE) as a marker for definition of the P/E boundary (Speijer 1994; Berggren & Abury 1996; Speijer *et al.* 1995).

The P/E boundary is located at the level of the first appearance of *Pseudohastigerna wilcoxensis* and *Acarinina willcoxensis* at Wadi Matulla section (Obaidalla 1999).

Faris *et al.* (1999), delineated P/E boundary at NP9 / NP10 boundary at G. El-Shaghab, El-Homra and El-Shanka sections, whereas this boundary lies within the upper part of the NP9 Zone at G. El-Sheikh Eisa, Umel-Ghanayem and Teir/Tarawan sections.

In the southwest Sinai sections (Wadi Feiran and Gabal Matulla), the *Morozovella velascoensis/Morozovella edgari* zonal boundary is taken as a good evidence to place the Paleocene / Eocene boundary. This level coincides with the NP9/NP10 zonal boundary at G. Matulla section, and within the upper part of NP9 in Wadi Feiran section. *Sphenolithus, Discoasters & Pontosphaeres* are the common genera within the topmost NP9-base NP10 (Paleocene/Eocene transition) in the studied succession.

CONCLUSIONS

The present work deals with the biostratigraphy of the Upper Cretaceous - Lower Eocene successions in southwest Sinai (Wadi Feiran and Gabal Matulla sections), by means of planktonic foraminifera and calcareous nannofossils.

These successions include three formations; Sudr, Esna and Thebes.

The stratigraphic distribution of the Late Maastrichtian - Early Eocene planktonic

foraminifera and calcareous nannoplankton, permits the recognition of 13 planktonic foraminiferal and 12 calcareous nannoplankton Zones.

In terms of the planktonic foraminifera, the K/P boundary in the studied sections is located at the extinction level of the Late Maastrichtian assemblages and by the FO of new species. The latest Maastrichtian is absent due to the absence of the calcareous nannofossil *Micula prinssi* Zone and the uppermost part of the planktonic foraminiferal *Abathomphalus mayaroensis* Zone in the investigated sections. Also, the basal Danian is not recorded due to the absence of the calcareous nannofossil *Markalius inversus* Zone and the planktonic foraminiferal *Globigerina eugubina* Zone.

The Danian/Thanetian boundary is placed at the top of the *Morozovella uncinata* Zone, and in the upper part of the *Ellipsolithus macellus* Zone in the studied sections. In the southwest Sinai sections (Wadi Feiran and Gabal Matulla), the *Morozovella velascoensis/Morozovella edgari* zonal boundary is taken as a good evidence to delineate the Paleocene/Eocene boundary. This level coincides with the NP9/NP10 zonal boundary of calcareous nannoplankton at Gabal Matulla section and within the upper part of NP9 of Wadi Feiran section.

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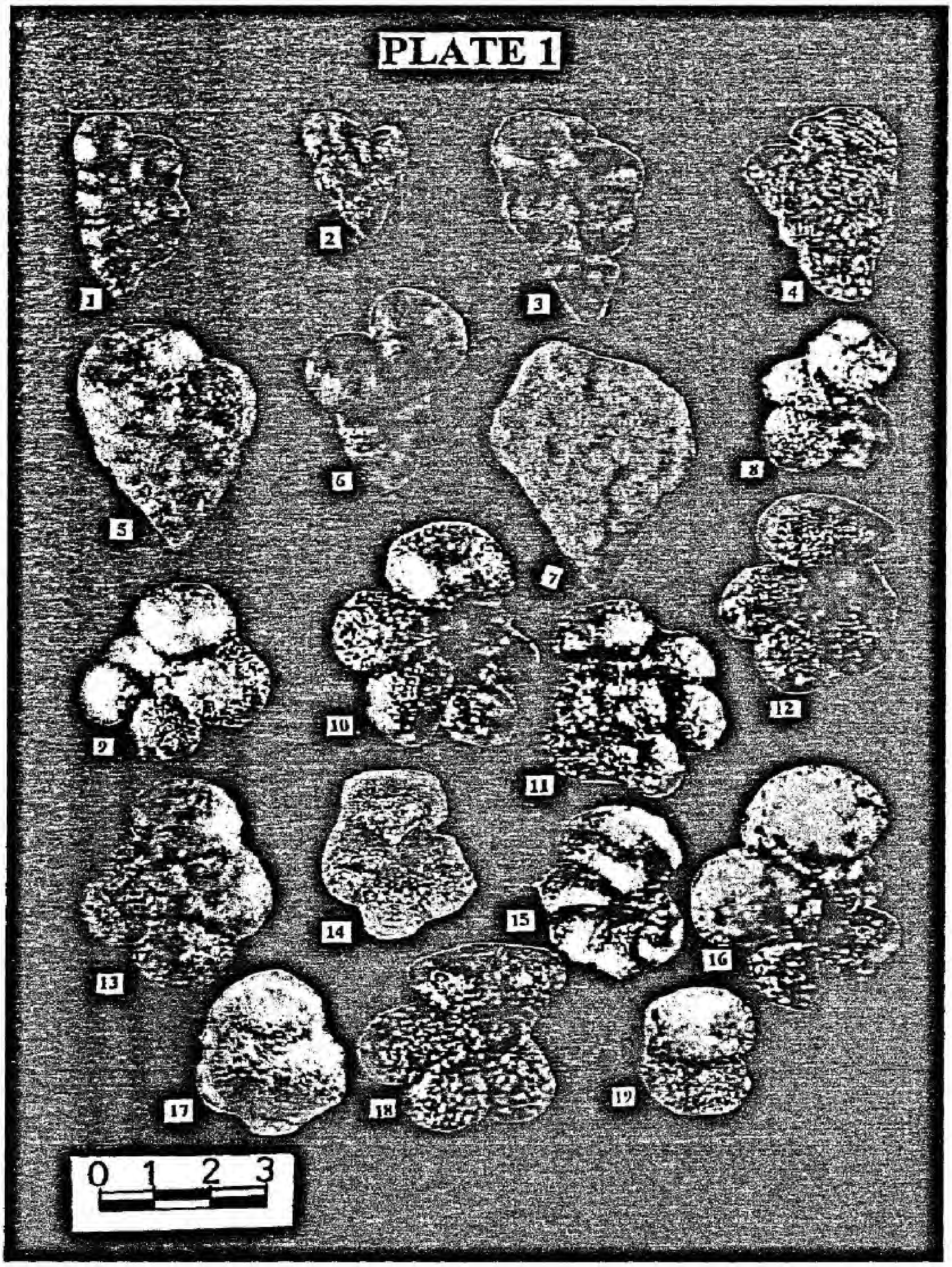
PLATE 1
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Plate 1
(All Figures X 75)

1	***Heterohelix navarioensis Loeblich Sample No 29, Ganssenina gansseri Zone, Wadie Feiran section.***
2	***Heterohelix striata (Ehrenbergy)*** ***Sample No 12, Gansserina gansseri Zone, Gebel Matulla section.***
3	***Heterohelix globulosa (Ehrenberg)*** ***Sample No 13, Gansserina gansseri Zone, Gebel Matuila section.***
4,5	***Pseudoguembelina exco0lata (Cushman)*** ***Sample No 16, Abathomphalus mayaroensis Zone, Gebel Matulla section.***
6	***Pseudotextularia elegans (Rzehak)*** ***Sample No 35, Abathomphalus mayaroensis Zone, Wadi Feiran section.***
7	***Racemiguembelina fructicos (Egger)*** ***Sample No 18, Abathomphalus mayaroensis Zone, Gebel Matulla section.***
9	*Morozovella trinidadensis (Bolli)* ***Sample No 45, Morozovella trinidadensis Zone, Wadi Feiran section.***
11	*Morozovella praecursoria (Morozova)* ***Sample No 25, Morozovella Angulata Zone Wadi Feiran section.***
12,13	***Morozovella pseudobulloides (Plummer)*** ***Sample No 35, Morozovella uncinata Zone, Gebel Matulla section.***
14,15	***Morozovella uncinata (Bolli)*** ***Sample No 48, Morozovella uncinata Zone,Wadi Feiran section.***
15	***Sample No 49, Morozovella uncinata Zone, Gebel Matulla section.***
16	*Morozovella angulata (White)* ***Sample No 52, Morozovella angulata Zone, Wadi Feiran section.***
17	*Morozovella aequa (Cushman & Renz)* ***Sample No 76, Morozovella formosa formosa Zone, Wadi Feiran section.***
18	*Morozovella subbotinae (Morozove)* ***Sample No 72, Morozovella subbotinaeZone, Wadi Feiran section.***
19	***Globigenina triloculinoides Plummer*** ***Sample No 53, Planorotalites pseudomenardii Zone, Gebel Matulla section.***

PLATE 2

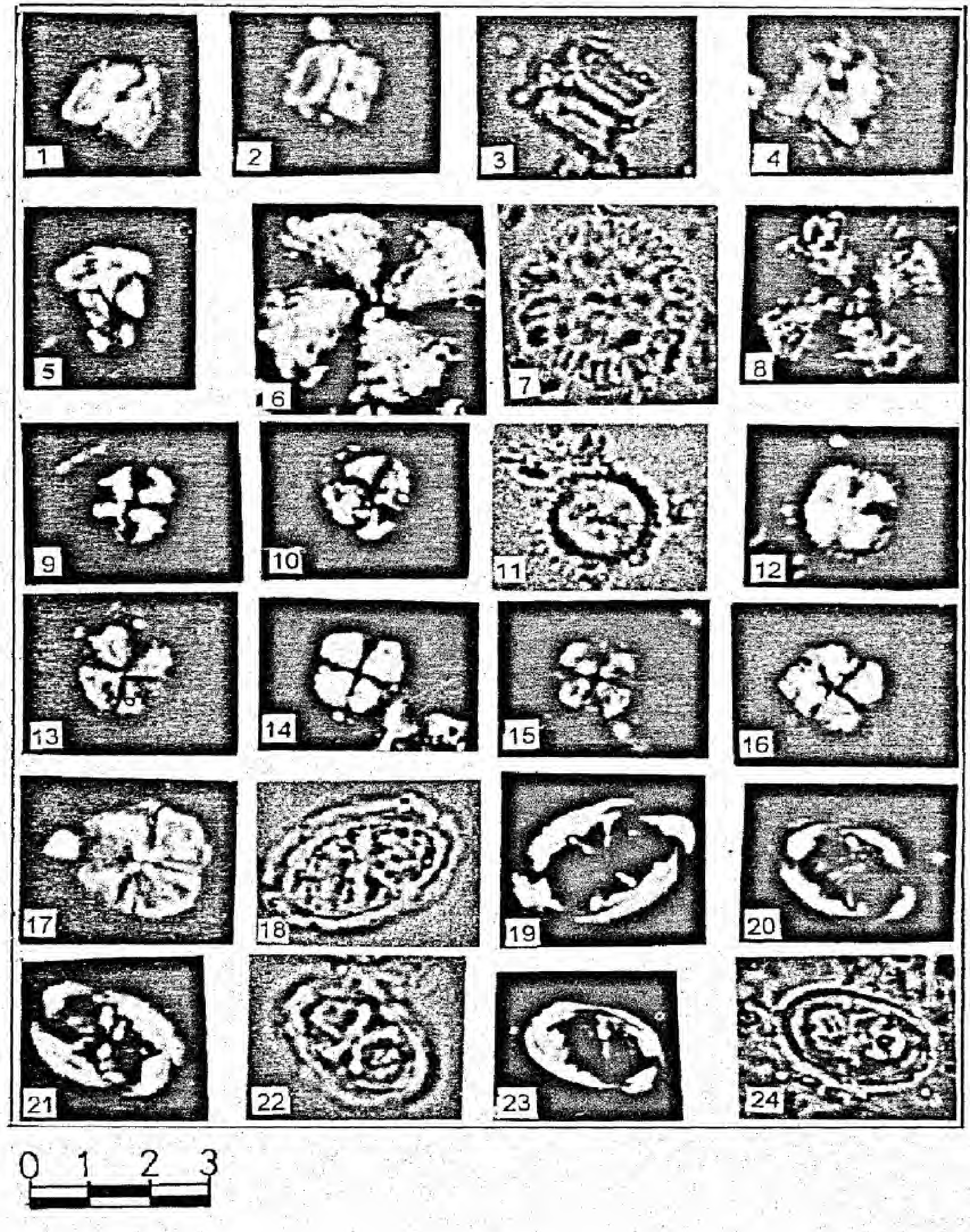

Plate 2

(All Figures X 2000)

1-2 Fasciculithus tympaniformis Hay & Mohler

1 Sample No. 40, Fasciculithus tympaniformis Zone, Gebel Matulla section.

2 Sample No. 66, Discoaster multiradiatus Zone, Wadi Feiran section.

3,4 Fasciculithus involutus Bramlette & Sullivan

Saple No. 66, Discoaster multiradiatus Zone, Wadi Feiran section.

5 Fasciculithus pileatus Bukry

Sample No. 57m Gekuikutgys jkeuboekkuuu Zibe, Wadi Feiran section.

6-8 Heliolithus kleinpellii Sullivan

6 Sample No. 47, Heliolithus kleinpellii Zone, Wadi Feiran section.

7 Sample No. 48, Heliolithus kleinpellii Zone, Gebel Matulla section.

8 Sample No. 15, Heliolithus kleinpellii Zone, Gebel Yellg section.

9-10 Bomolithus elegans Roth

9 Sample No. 64, Discoaster multiradiatus Zone, Wadi Feiran section.

10 Sample No. 44, Fasciculithus tympaniformis Zone, Gebel Matulla section.

11-12 Heliolithus cantabriae Perch-Nielsen

Sample No 59, Heliolithus kleinpellii Zone, Wadi Feiran section.

13.16 Sphenolithus primus Perch-Nielsen

13 Sample No. 61, Discoaster mohleri Zone, Wadi Feiran section.

14 Sample No. 63, Discoaster multiradiatus Zone, Gebel Matulla section.

15 Sample No. 77, Tribrachiatus contortus Zone, Gebel Matulla section.

16 Sample No. 28, Ellipsolithus macellus Zone, El-Hassana section.

17 Sphenolithus moriformis Bramplette & Wilcoxon

Sample No. 54, Discoaster binodosus Zone, El-Hassana section.

18-24 Neochiastozygus junctus (Bramplette & Sullivan) Perch-Nielsen

18-19 Sample No. 69, Discoaster multiradiatus Zone, Gebel Matulla section.

20 Sample No. 51, Tribrachiatus contortus Zone, El-Hassana section.

21.22 Sample No. 64, Discoaster multiradiatus Zone, Wadi Feiran section.

23,24 Sample No. 62, Discoaster multiradiatus Zone, Gebel Matulla section.